Dick Manning's Plain English Guide To Flamecutting Machines

TORCHES and TIPS

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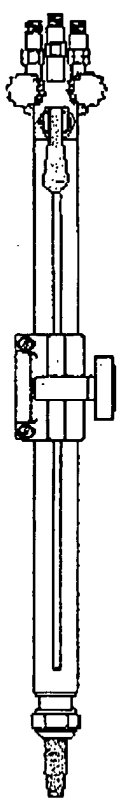

A sketch of a typical 3-hose, 3-valve machine torch is shown at the left, installed in a *torch holder.* These torches usually have an 18" long brass body, and are designed for mounting on a cutting machine, rather than being hand held. The torch holder has a handwheel to adjust the height of the torch through a rack-and-pinion mechanism.

Interchangeable nozzles called cutting tips are installed at the lower end of the torch. The tips come in a variety of sizes and styles for various fuel gasses and material thicknesses. They are retained by a threaded *tip nut.*

None of the common fuel gasses will burn hot enough to heat steel sufficiently if they are burned in air. They must first be mixed with oxygen, and then ignited, providing a very hot flame temperature. All cutting torches provide the means to do this.

The oxygen used to burn the fuel gas is called preheat oxygen, as distinguished from the cutting oxygen, which takes a separate path through the torch and exits through a center hole in the tip.

The fuel gas and two sources of oxygen must be supplied to the torch through separate ports in order to allow independent pressure regulation of each from different sources. Three inlet fittings are shown at the top of the torch. The cutting oxygen enters at the center fitting; preheat oxygen enters at the left, and the fuel gas enters at the right.

Two adjustable valves to open and regulate the preheat oxygen and fuel are required, and a third valve for the cutting oxygen is usually desirable. This torch uses a quick-acting poppet valve with a lever handle for that purpose, but other styles are common. It is not necessary to regulate cutting oxygen at the torch, so the adjustable feature is not required and these valves are used either fully open or shut off. Some machines have separate external shutoff valves for the cutting oxygen, and the corresponding valve is not strictly necessary on those machines. But

I recommend them on the torch anyway as a manual override.

Other styles of torches are available that lack one or more of these ports or valves, but they are not practical for multi-torch operation on large flamecutting machines.

For safety, additional one-way check valves are used at the inlet of the preheat fuel and oxygen ports. These prevent either of the gasses from flowing backwards into the supply hoses and creating an explosive hazard. They should also be used on the cutting oxygen port unless the machine has a separate cutting oxygen solenoid valve for each individual torch. Some torches are made with these check valves built in, but most require that you add them separately.

When the user opens the two preheat valves, the torch will direct the gasses to the upper end of the cutting tip. The gasses will be mixed to form a highly combustible mixture. The gas exits the tip through a ring of fine ports at the front of the tip, where they are ignited by the user.

The flame characteristics can be adjusted by trimming the two preheat torch valves as needed, based on experience.

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TORCH DETAILS & VARIATIONS:

The preheat oxygen and fuel can be mixed either within the torch body, or delivered separately to the tip and mixed inside the tip, depending on the method of torch construction. You can tell which style is used by looking at the number of *seats* on the cutting tip. Three seat tips allow fuel and preheat oxygen to enter separately. Two seat tips require that the gasses be mixed inside the torch before entering the tip together.

Conflicting claims arise from the various manufacturers about these features.

Those who make mix-in-the-tip styles claim that they can be used for any gas because a new mixing chamber is installed every time you change a tip. This allows tips to be optimized for each gas, provides a broader range of operating characteristics and prevents flashbacks from entering the torch body.

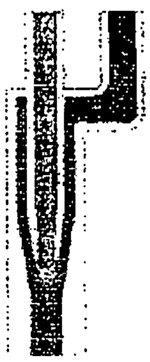
The ability to use any gas is important in plants that have several types of fuel gas available. But many users have standardized on one gas, so this isn't always a factor. And very low pressure fuels such as natural gas cannot be delivered properly in this system, despite the "all gasses" claim.

Tips for these torches will be slightly more expensive than other types because of the extra machining involved, but the torches may be less expensive and any backfiring will be confined to the tip and not enter the torch body, preserving torch life.

Those making mix-in-the-torch claim that better flow characteristics can be built into the torch. This includes *injectors* that are needed for use with natural gas and can be helpful with other fuels.

Both systems are popular and work quite well. All of the major name brands are well supported by their dealers and alternate sources of tips, spare parts and repair services are available from

independent sources.



A sketch of a typical injector used for natural and sometimes other gasses is shown at the left. These are venturi-like devices which that use the flow of preheat oxygen to create a vacuum on the fuel supply line. This corresponds to the method used in carburetors to draw gasoline into the passing intake air stream. Applied to a cutting torch, this principle helps boost the fuel flow for better combustion.

The injectors usually have a "tube-inside-a-tube"construction having carefully positioned and tapered nozzles and chambers inside. This one is for very low pressure fuels; oxygen enters at the center port and its velocity as it exits the center port creates a draft that pulls fuel from the surrounding cavity, mixing the two. Other styles of injectors for higher pressure fuels might admit the fuel through the center, and have a slightly different configuration. The injector shown is a generalized design - it doesn't represent any particular manufacturer's product.

The vacuum is needed because natural gas is often supplied from utility piping sources at pressures as low as six ounces per square inch. Not enough gas will flow even if all of the fuel valves are wide open. These are called *injector* or *low pressure torches*; they can also be used with other fuel gasses, but NOT ACETYLENE!

Torches which do not have injectors can be used for most other fuel gasses, and are called *positive pressure*, or sometimes *equal pressure torches*. These can be used with natural gas if it is available pumped to a higher pressure.

There are also *universal pressure torches* that have injectors and can be used for acetylene. They are a not used frequently in the industry. In most cases, I recommend against the use of acetylene in mechanized cutting.

Injectors must be built into the torch body; it's difficult to incorporate this feature inside a tip.

The mixture of fuel gas and oxygen is quite explosive and can be unsafe. Acetylene is by far the most dangerous gas in this regard. Torches and tips are designed to deal with this, and properly maintained and used, this is a reasonably safe process with either style of torch.

For very heavy cutting, *mill torches* are sometimes used. These use large tips which have a heavy preheat flame and a huge oxygen port. They are primarily found in shops that do a lot of very heavy cutting. Many flamecutting machines cannot provide enough oxygen flow to use these, and the machines must be modified. In most cases, a standard torch will do fine, they can cut up to 14".

Some mill torches are made with water cooling. These are intended for use in steel mills; I have never seen one in ordinary plate shops.

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TIPS:

Cutting tips are the fundamental element that makes flamecutting work. They are the single most important item in determining the quality of the cut, providing a dead straight jet cutting

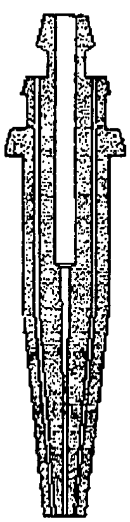
oxygen and a stable, safe preheat flame. A lot of science and precision manufacturing goes into making them exactly right; and they must be kept in good condition.

A wide variety of tips is available. They come in one piece, two piece, two seat, three seat, conical or flat seats, straight bore, divergent bore, high, medium or low heat ranges and some are swaged. The two piece tips can have either flush or recessed inserts. All styles are supplied in a range of sizes for various thicknesses of steel to be cut and fuels to be used.

But selecting the basic style isn't all that complicated. The first decision is the choice of fuel gas; the second is the choice of a cutting torch. These two factors will determine the general construction of the tips used. Torches and tips are designed according to the combustion characteristics of the fuel category, and they either will not work well or are dangerous when used with the wrong fuel.

All manufacturers publish a *tip chart* for use with each style of their tip products. These charts indicate the size of tip to be used for cutting the desired thickness of steel, and a suggested range of cutting oxygen pressures and speeds to be used, along with an estimate of the slot width, or *kerf*, the tip will make as it cuts. Most will indicate at least the cutting oxygen consumption so you can estimate the volume and flowrate needed.

Most users develop their own preferences after a while based on their experience, but the manufacturer's charts are a good starting point. No shop should be without them, but you can certainly take exception to the charts if you find other settings that work better for you.



A typical one-piece tip is shown here in cross-section. It is made of solid round slug of copper alloy. The one shown has three seats in a conical configuration and mixes the fuel and preheat oxygen internally.

A number of small holes are drilled all the way through it's length: a center hole for the cutting oxygen, several around more around that are for the preheat flame and small angled holes near the top allow the preheat oxygen to enter the tip. The cutting oxygen enters at the top center and flows straight through the tip. The fuel enters between the top and middle seats, the preheat oxygen between the lower two seats.

The bend and taper in the drilled holes is accomplished by a process called *swaging*. The end of the drilled slug is squeezed between pressure rollers and rotated during manufacturing. This reduces its diameter in that region, and squeezing the holes down in size as it does so. Fine wires are inserted into the holes before swaging in order to control the size of the holes as they are reduced. The wires are then removed, leaving perfectly finished holes.

Swaging provides a gradual taper in the holes as they approach the exit region, which has straight bores. Some claim this tapering reduces turbulence in the oxygen flow and provides a better cut. It also provides good control of the preheat gas exit angle.

Gas flows always become turbulent whenever there is a sudden change in their path, such as you see at the stepped bore at the midsection of this tip. The long exit bore however gives the flowstream a chance to straighten out, and the gradual tapering further reduces the diameter with a minimum of turbulence. I tend to agree with the tapering concept for this reason,

although there are many acceptable tips on the market that lack this feature.

Solid copper tips work well for acetylene which has a fast rate of combustion and high flame temperature.

Other gasses such as propylene, MPS, and other proprietary "hot" gasses burn at a slower rate than acetylene, and propane and natural gas burn even slower. These gasses can use two piece tips, which are easier to make with a large number of ports to provide a more even heat distribution.

The two piece tip shown here consists of a copper outer shell and a separable inner insert, usually made of brass. This one has a two seat flat construction; the insert is shown cutaway at the very top. The two seat feature requires that the fuel and preheat oxygen be mixed before entering the tip.

As with all tips, the cutting oxygen enters through the top center port. Mixed fuel and oxygen are admitted through an annular groove between the two seats, then flowing through some dilled holes to the lower end.

The center insert fits against the inner taper of the shell closely at the lower end, but it leaves a cylindrical space towards the top for the mixture to pass. It has a large number of fine slots milled towards the exit end of the tip. These allow an exit path for the flammable gasses to leave with enough velocity that the flame is retained evenly around the tip face and backfires are minimized.

Note that the lower end of the insert of this tip is recessed somewhat from the bottom of the shell. This feature is required for use with cool gasses such as propane and natural gas - it helps provide stable flame retention. Gasses such as MPS, propylene and other hot fuels require that the insert be flush with the end of the shell or nearly so. Otherwise, they would heat the rim of the shell too much. The two styles are not interchangeable - you must use the correct style for your fuel gas, or you will have either poor performance or a safety problem.

These are only two examples of the large variety of tip styles on the market. Many other seat configurations are popular. Not all one-piece tips are swaged, and some two piece tips are. One piece tips can be made for almost any gas, using two or three seats.

Acetylene however is too aggressive for the two-piece design. Relatively few slots would be needed to deliver enough heat, and acetylene backfires too easily if the insert is not gas tight against the shell.

Almost universally the tip seats are made of carefully finished sold metal. Many resilient materials would either be destroyed by the heat present or be subject to damage by dirt too easily. The Smith tip however does use a soft material for the seal of the center oxygen port only.

The metal seats also allow good heat transfer to the torch. Copper has an excellent ability to conduct heat and that is one reason why it is used for tips. Torches are not necessarily designed to dissipate huge amounts of heat, but they at least provide a path to help it drain away from the tip. That helps the tip stay a little cooler.

If the tip gets too hot in operation, the flammable mixture inside can backfire. Remember that

the oxygen is already mixed in with the fuel by the time they are inside the tip, so the mixture doesn't need atmospheric air to burn. It can ignite spontaneously as soon as it gets hot enough and burn inside the torch or tip. This is a dangerous situation - a fire inside the torch can destroy it, or flash back up the hoses and burn other parts of the machine. In either case, you have the potential for a major safety hazard. Shut the gasses off immediately and let the torch cool down. Tips can also backfire if the burning fuel mixture is blocked, such as by touching the tip down onto the work, or perhaps a piece of flying slag blocks a port. Acetylene and MPS are more prone to this than most other fuel gasses.

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DIVERGENT TIPS:

Some tips are made with a divergent bore at the cutting oxygen outlet; these are known as *high speed* tips. The port has a slight outward flare near the end of the tip. The purpose of this is to help the cutting oxygen expand smoothly and this, believe it or not, helps the oxygen stream accelerate forward, rather than to the side. This in turn, permits a higher oxygen flowrate to be used, allowing increased cutting speed. The angle of divergence is so slight that you can hardly see it.

The cutting oxygen enters the tip compressed at line pressure and races towards the outlet constrained only by the small size of the port. The pressure drops as it approaches the end of the tip, the gas expands in volume as the pressure falls, and the expansion forces it to accelerate even faster as it moves through the tip in order to maintain the same flowrate.

By the time it leaves the tip, the oxygen is travelling faster than the speed of sound - sometimes much more than that, depending on the tip design. Using tip charts from several manufacturers, I calculated the velocity required to push the recommended flowrate of oxygen, at atmospheric pressure, through the tiny bore sizes specified. I found speeds ranging from 1600 to 4000 feet per second, which correspond to 1090 and 2720 miles per hour respectively. The speed of sound in air is only 1100 feet per second, or 750 miles per hour. Admittedly, the flow of compressed gas through pipes is much more complicated than this, and the oxygen doesn't quite expand down to atmospheric pressure while it's inside the tip, but these estimates are close enough for this discussion.

When it finally exits the tip, it has considerable forward momentum because of that speed, and it tends to continue in straight line. But this isn't a perfect process. Once out of the tip, the oxygen is free to expand to the side a little, which it does because the stream is still at a slightly higher pressure than the atmosphere. The presence of the preheat flame gasses helps to limit and control the expansion. But the oxygen jet diameter is usually larger than the port it exited, and it had to expand sideways to do that.

If too much oxygen is forced through a straight bore tip by increasing the pressure, the lateral expansion becomes more pronounced. It creates too much turbulence as it expands and that wastes oxygen and affects the cut - and not for the better. This is why you can't keep increasing the oxygen pressure indefinitely and expect better performance.

Divergent bore tips allow the gas to start expanding in a controlled manner before it leaves the tip. This gives the gas more forward momentum, reduces the tendency to expand outside the tip

and reduces some of the turbulence in the oxygen after it leaves the tip.

By controlling expansion better, divergent tips permit a much higher flow of oxygen to be used for cutting than straight bore tips allow, and they deliver it at higher speed. And that permits faster cutting.

These high speed tips require higher oxygen inlet pressures than straight bore tips, and they may have a hotter preheat range to accommodate the faster cutting speed.

Tips are also made with high, low or medium preheat ranges. For most machine cutting, a medium or sometimes even a low preheat range is preferred. Nearly all machines have adjustable gas controls, and these can be used to change the preheat flame to suit most conditions easily.

The high preheat tips may be useful for rusted or scaly plate, but most times you can simply turn up the pressure on the preheat gasses.

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TIP MAINTENANCE:

Even slight imperfections in a tip will cause leaks and poor cuts. So it's important to take good care of them.

Unfortunately, tips take a lot of abuse because they are so near the heat of the cut. Flying slag is probably the worst offender. Little particles of it cling to the face of the tip, sometimes partially blocking the holes and creating turbulence. The other common problem is wear. Either of these problems can disturb the gas flow enough to create uneven heating and rough cuts.

The edges of the ports must be dead square and sharp at the end of the tip. If you can see light reflecting from the edge of a hole, it's not sharp, it's *bellmouthed*, and that' a sign of wear. Rough brushing or reaming of the port may to be the most likely causes. Once a tip is worn, it may not cut properly. This is especially critical for the cutting oxygen port. Sometimes a problem here is only evident when cutting in a particular direction - either the cut is rough or it has an uneven kerf.

The copper and brass materials used in tips will wear if brushed too heavily. Always brush the slots on two piece tips parallel to the flutes. Push slag particles out from the backside of the tip when possible. And use a very fine file or a face reamer on the front of the tip.

Tip cleaning kits are available with various sizes of fine ribbed wires to clean the holes. A thin piece of metal can be used to straighten the flutes of two piece tips.

Seats are generally difficult to repair once they are damaged. The most common problems I have found are due to contamination or rough handling. It is easy to get a small piece of dirt on the seats from your hands, particularly if you are using dirty gloves, when installing them into the torch. Then the dirt crushes into the seat face, and possibly into the torch seat, when the tip is tightened into the torch.

Once the torch seats are damaged, they may not seat properly with, and can even ruin, any tips

subsequently installed, particularly if dirt has lodged in their seats. Pretty soon, leaks start spreading around like a contagious disease, and half the torches on the machine have chronic flames leaking out at the tip nuts. I've seen more than one shop with this problem and, worse yet, the users think this is perfectly normal. Please don't do that - it's dangerous - get the torches fixed. Torch seats can be refaced by a rebuilder using special reamers.

It's easy to avoid all of this by handling tips carefully when installing and keeping them neatly in a rack when not in use. With proper care, a set of tips can last a long time, sometimes for years.

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